LASER ^{40}AR/^{39}AR ANALYSES OF PHLOGOPITES FROM KIMBERLITES AND THEIR XENOLITHS: CONSTRAINTS ON ERUPTION AGES OF SOUTHERN AFRICAN AND SIBERIAN KIMBERLITES AND MANTLE VOLATILE COMPOSITIONS.

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Determining kimberlite eruption ages is of great economic importance in the search for diamonds but has proven to be very problematic and time consuming. Previous attempts at K-Ar and conventional step-heating Ar analysis of kimberlite and xenolith-derived phlogopites have identified considerable "excess" radiogenic argon that results in some "ages" being considerably older than the accepted eruption ages (e.g., Phillips and Onstott, 1986). The laser ^{40}Ar/^{39}Ar technique offers a rapid, insitu technique for dating individual mineral grains following their irradiation and has been previously applied to kimberlites and diamond inclusions with varying success (Burgess et. al., 1989; Phillips, 1991; Phillips and Onstott, 1986; Phillips et. al, 1989). A detailed laser-probe study (Phillips, 1991) of xenolith and kimberlitic phlogopites from southern Africa revealed considerable systematic and non-systematic zonation of "excess" Ar and Cl concentrations across {001} cleavage surfaces. Clearly, in such cases the conventional step-heating and K-Ar methods do not yield reliable ages. In this study we have analysed phlogopites from xenoliths and the host kimberlite from southern Africa and Siberia to:
a) estimate the eruption ages of some important, un-dated diamondiferous and non-diamondiferous kimberlites, b) further constrain the origin of the abundant, apparent "excess" argon detected by previous studies by examining in-situ spatial variations with the laser probe, and c) acquire information about the nature and origin of deep mantle metasomatic fluids and their possible relation to diamond formation.

At least three and often over 10 spots were analysed from each grain, depending on their size. Two types of Ar isotopic zonation are observed which directly translate into variation in "apparent ages". Firstly, phlogopites that appear as phenocrysts or macrocrysts in the kimberlites yield ^{40}Ar/^{39}Ar values that are either invariant, or that vary in a non-systematic manner across the grain. This behaviour has been observed in some phlogopite xenoliths from the Swartruggens kimberlite (Phillips, 1991). Secondly, phlogopites from glimmerite, mica-peridotite or crustal xenoliths have old core ages which decrease rimwards (see Fig.). The xenolith rim "ages" approximate the eruption age of the kimberlite pipe given by U-Pb zircon measurements (Davis et.al., 1980), recent perovskite U-Pb determinations (Kinny et al, this volume) but in most cases are above this value (see Fig.). The lack of pronounced core-rim age zonation in the phenocrystal and macrocrystal phlogopites in Table 1 suggests that the mean ages may approximate the emplacement age of the kimberlite pipe. This is supported by the good agreement between the ^{40}Ar-^{39}Ar age of Udachnaya (east) given by U-1 and two recent perovskite ^{206}Pb/^{238}U ages of 376 ± 3 and 374 ± 5 Ma (Kinny et. el., 1995). This age is higher than that usually reported for Udachnaya. We also note that the two laser-probe Ar-Ar ages for Mir are in the same range as Udachnaya but significantly older than the 351 ±7 U/Pb age for Mir determined by Davis (1980). More within grain age variation exists in the Mir phlogopites compared to U-1 and it is possible that the high ages are influenced by "excess" argon. Significantly, individual spot analyses on the rim of M(a) range down to 355 Ma.

^{40}Ar/^{39}Ar ages for the xenolith phlogopites are much more variable (see Fig.) and the variations with individual grains are characteristic of diffusion profiles. Phillips (1991) found that ages at the rims of xenolith phlogopites are close to the accepted age of pipe emplacement. This was also the case for phlogopites we analysed from two South African kimberlites (Letseng and Kampfersdam). In contrast, ages of the rims of phlogopites from the Udachnaya xenolith UV22/72 do not come 1Ga of the eruption age of the kimberlite (Fig.). Given the high Ar diffusivity in phlogopite at mantle temperatures, e.g., a 1mm diameter grain should totally homogenise in less than a year at 1000°C this difference in the age profiles across the grains studied here may imply faster eruption rates compared to the South African kimberlites. All the South African pipes studies so far exhibit Ar loss over virtually the whole grain whereas the Udachnaya samples exhibit relatively less Ar loss. This observation and other evidence such as the lack of resporbtion of Udachnaya diamonds and the presence of mantle xenoliths weighing up to 120 Kg suggest a more rapid ascent for this kimberlite compared to South African examples. The observation that Ar isotopes in large phlogopites (1mm or more) from kimberlites are not fully homogenised supports estimates of total ascent times of 2-15 hrs.

Table 1: Averaged $^{40}Ar/^{39}Ar$ ages of kimberlite phenocrysts and macrocrysts from Siberian kimberlites. Ages are the mean of several spot analyses on a single phlogopite grain.

Sample	Mean age (Ma)	± (1σ)	no. spots/grain
Mir			
Mir (a)	382	11	5
Mir (b)	372	12	5
Udachnaya (east)			
UV-1	374	7.5	3
Obnazhennaya			
O-1	416	36	7
Leningrad			
L-1	385	22	3

A major question arising from the data is whether the high ages in the cores of the grains (over 2 Ga older in the case of UV22/72) which are far older than the pipe-emplacement age, are merely the product of trapped "excess" Ar in response to elevated fluid pressures (Phillips, 1991), or indicative of the actual formation ages of the phlogopites in the mantle. The 2.1 to 2.4 Ga "ages" in the core of UV22/72 are within the range of Re-Os model ages observed in Udachnaya peridotite xenoliths (Pearson et. al., 1995) and mantle zircon ages of 1.8 to 2 Ga have been reported from Yakutian kimberlites (Kinny et. al., this volume). Is this similarity in ages, just co-incidental or could the ancient Ar ages represent a metasomatic event introducing high-K fluids/melts into the Siberian lithosphere? However, at mantle conditions Ar can only be retained by phlogopite in an environment of high *p*Ar or where there is no fluid phase to transport it large distances along intergrain boundaries. It is currently unclear whether the high radiogenic Ar concentration has accumulated accumulated due to K decay since the formation of the phlogopite, whether the phlogopite acted as a sink for transient fluids rich in radiogenic Ar, or whether the phlogopite crystallised just prior to eruption from fluids carrying radiogenic Ar from other parts of the lithosphere. The existence of fluids in the lithosphere containing a high inventory of radiogenic Ar has been demonstrated from diamond inclusion studies (Ozima et al., 1989; Burgess et.al., 1992). It is hoped that studies of the relationship between Ar systematics and other isotope systems in other kimberlites will illuminate this paradox.

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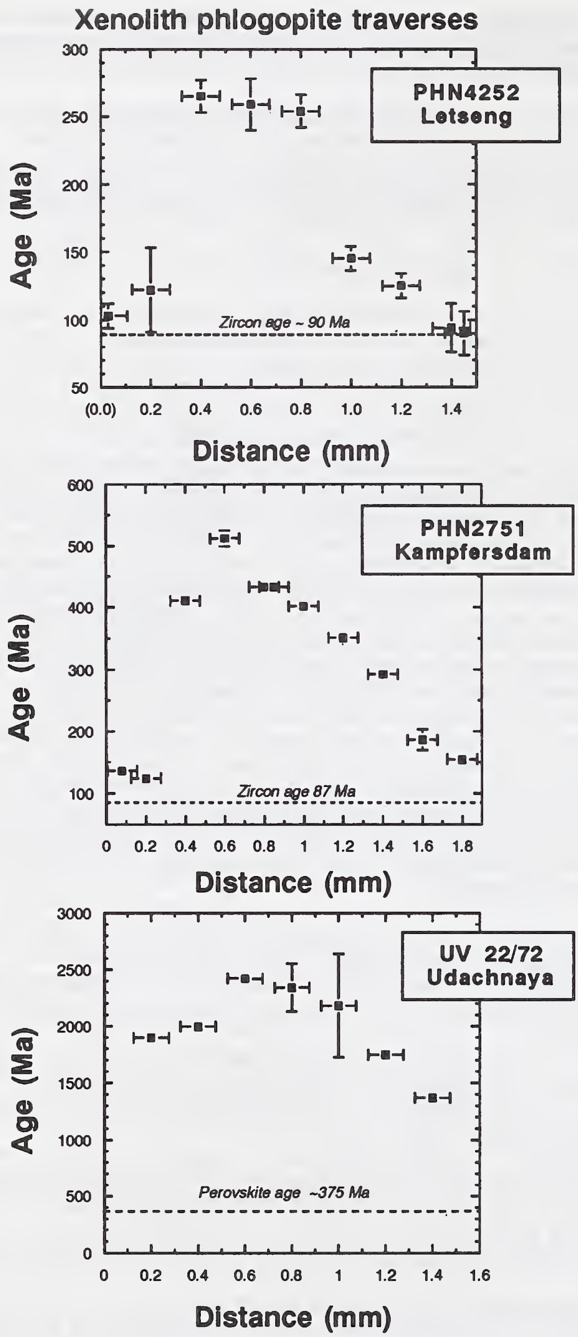

40Ar/39Ar spot age vs. distance across xenolith-derived phlogopites